PTO 05-2789

Japan Kokai

Document No.57-142525

MEASUREMENT OF OUTPUT DISTRIBUTION OF HEATER

(Hita no Shutsuryoku Bunpu no Sokutei Hoho)

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UNITED STATES PATENT AND TRADEMARK OFFICE

Washington, D. C. March 2005

Translated by: Schreiber Translations, Inc.

Country	:	Japan
Document No.	:	57-142525
Document Type	:	Kokai
Language	:	Japanese
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Applicant	:	Toshiba Corp.
IPC	:	G 01 J 5/02
		G 01 K 3/00
		//G 01 D 1/16
Date of Filing	:	February 27, 1981
Publication Date	:	September 3, 1982
Foreign Language Title	:	Hita no Shutsuryoku Bunpu no Sokutei Hoho
English Title	:	MEASUREMENT OF OUTPUT DISTRIBUTION OF HEATER /1[1]

SPECIFICATION

I. Title of the Invention

MEASUREMENT OF OUTPUT DISTRICUTION OF HEATER

II. Claims

The present invention is a method for measuring the output distribution of heater with a non-uniform output distribution and is characterized by finding a relationship between the surface temperature and the output in a reference heater with a uniform output distribution by same specification as a measurement objective heater, then energizing said measurement objective heater to measure a surface temperature at each spot, con-verting these measured surface temperatures to outputs from the relationship between said surface temperature and output and finding the output of said measurement objective heater at each spot.

[Detailed Description of the Invention]

The present invention relates to a method for measuring the output distribution of a heater with a non-uniform output distribution, such as sheath heater, etc.

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[1]Numbers in the margin indicate pagination in the foreign text.

For example, a sheath heater having a sine-wave output distribution characteristic (exothermic distribution characteristic) in the axial direction has been used as pseudo exothermic body of nuclear fuel.

When the measurement and inspection of output distribution characteristic in a manufacturing process of this type of sheath heater, a method wherein the resistance of exothermic body provided in an outer pipe is partially measured and the output characteristic (exothermic characteristic) is checked from resistance value of this exothermic body in a step prior to completing a product as sheath heater has been adopted before. Thus, since the inspection of this exothermic body is made on the way of manufacturing process, the outer pipe is squeezed by swaging it in the manufacturing process after the inspection or changing the resistance value of the exothermic body with a temperature rise caused by energization, etc., and a difference occurs between the inspection value and actual output distribution characteristic in the product of sheath heater.

Recently, when the safety, heat transfer characteristics, etc. of a nuclear reactor are analyzed, it has been required that a sheath heater used as pseudo exothermic body take an output distribution characteristic close to characteristics of actual fuel rods as far as possible for improvement of analysis

accuracy. Therefore, it is important to accurately measure the output distribution characteristic of sheath heater. /2

The present invention was made in view of said circumstance and is to provide a measuring method for output distribution of heater which can accurately measure the output distribution characteristic in a product of heater with a non-uniform output distribution.

The output distribution measuring method of heater of the present invention is a method for measuring the output distribution of heater with a non-uniform output distribution and is characterized by finding a relationship between the surface temperature and the output in a reference heater with a uniform output distribution by same specification as a measurement objective heater, then energizing said measurement objective heater to measure a surface temperature at each spot, converting these measured surface temperatures to outputs from the relationship between said surface temperature and output and finding the output of said measurement objective heater at each spot.

The present invention is illustrated below.

The basis of output distribution measuring method of heater of the present invention is described.

In the measuring method of present invention, a relationship between the surface temperature and the output is

found by taking a heater with a non-uniform output distribution characteristic (exothermic distribution), e. g., a sheath heater having a sine-wave output distribution characteristic in the axial direction as measurement object, using a reference heater with a uniform output distribution characteristic, e. g., a sheath heater by same specification as heater of this measurement object, energizing this reference heater under such conditions that the heater outputs are different, respectively and measuring the surface temperature of heater at each output. The material of outer pipe and specifications such as outside diameter, inside diameter dimensions of said reference heater made equal to those of the measurement objective heater, the lengths of outer pipe and exothermic body may be not necessarily equal. However, the material and dimensions of parts of the exothermic body are so set up that it can be heated with a uniform output distribution in the axial direction. When measurements on the reference heater are performed, the exothermic body is ener-gized, e. g., by applying various different voltages to the body to measure the surface temperatures of outer pipe in accordance therewith. The output of heater is found by voltage × current, i. e., a power value under conditions of energizing the exother-mic body. This power value is further taken as output of heater per unit length by dividing it with the heating length of outer pipe. The surface

temperature of outer pipe is measured, e. g., with a radiation thermometer or a brightness thermometer. In this manner, a relationship between various outputs per unit length of reference heater and surface temperatures correspon-ding thereto are found, consequently a diagram that depicts a characteristic line connecting the outputs and the surface tem-peratures is prepared as shown by Fig. 2. This relationship between the outputs and the surface temperatures becomes a model of a relationship between the outputs and the surface tempera-tures in the measurement objective heater.

Next, surface temperatures of parts in the axial direction of heater are measured for the measurement objective heater prepared as a product, i. e., a finished product, e. g., a sheath heater having a sine-wave output distribution characteristic in the axial direction. Moreover, the exothermic body in this sheath heater is allowed to have different materials, shapes and dimensions to vary electric resistance values of the parts so that the body has a sine-wave exothermic distribution in the axial distribution, for example, they forms a coil con-necting plural materials having different resistance values. As shown in Fig. 1, terminals **3**, **3** at both ends of an outer pipe **2** in a sheath heater **1** are connected to a power source, if an exothermic body inside the outer pipe **2** is energized, the exothermic body is heated and the surface

temperature of outer pipe 2 rises. Surface temperatures at the axial center point and at axial multiple spots coming to left-right both ends with the center point as center in the sheath heater 1, i. e., the outer pipe 2, are measured with a radiation-type thermometer 4 such as radiation thermometer or brightness thermometer, etc. In this case, the radiation-type thermometer is non-contact type and can instantly measure the temperature, therefore the surface tem-peratures of the spots of outer pipe 2 can be measured quickly and accurately. The surface temperature of outer pipe 2 has a sine-wave output distribution in the axial direction in which the surface temperature is the highest at the center point and gradually decreases toward the both ends, as shown in a characteristic diagram of Fig. 3, a surface temperature distribution characteristic line forming a sine wave is depicted like a connecting line D of axial distance and exothermic temperature of the sheath heater. The surface temperatures of the axial spots in outer pipe 2 thus measured are converted to outputs per unit length based on the relationship between the output and surface temperature found formerly by using the reference heater. Namely, the outputs per unit length are found from the surface temperatures according to the characteristic line of output and surface temperature in the characteristic diagram of Fig. 2. Therefore, - the outputs /3

per unit length of spots at the center point and the both ends can be found according to surface tempera-tures, respectively. Accordingly, the output distribution in the product of sheath heater can be found. If the axial distances and outputs of the sheath heater are connected as shown by the characteristic diagram of Fig. 3, an output distribution charac-teristic line corresponding to the surface temperature output characteristic and forming a sine wave like a line E is obtained.

Then, in the step of designing the measurement objective sheath heater, a design surface temperature distribution and a design output distribution in the sheath heater are set up, respectively, the measured surface temperature distribution and output distribution of the product of sheath heater found formerly are contrasted with these design surface temperature distribution and output distribution to find a slippage of values of the measured surface temperature distribution and output distribution and the design values. When the surface temperature distribution and output distribution of said sheath heater product are within a predetermined range to the design values, these results are qualified as a product.

In this manner, the output distribution in the product of measuring objective heater is measured.

[Actual Example]

A measurement objective heater is taken as a sheath heater having a sine-wave output distribution in the axial direction, this sheath heater is made of a stainless steel (SUS316) and equipped with an outer pipe forming an outside diameter of 6.5 mm. In this sheath heater, the axial distances of measurement spots from the exothermic center position are shown in a column A and the design outputs per unit length (W/cm) at these spots are shown in a column B in the following table.

A reference heater is equipped with an outer pipe of same material and same outside diameter as the outer pipe of said measurement objective sheath heater, a sheath heater with a uniform exothermic distribution was prepared, this sheath heater was energized to measure the surface temperature for each spot, and a characteristic diagram expressing the output per unit length and the surface temperature shown in Fig. 2 was prepared based on a relationship of the two heaters. Moreover, the design surface temperatures versus the design outputs of spots in the measurement objective sheath heater were found according to this diagram. They are shown in a column C of table.

Subsequently, the measurement objective sheath heater was energized under conditions of voltage 10 V and current 8.3 A to measure the surface temperatures of spots. This result is shown in a column D of table. The surface temperatures were measured

by an IR radiation thermometer by supporting both the reference heater and the measurement objective heater in air. Moreover, the surface temperatures of spots of said sheath heater were converted to corresponding outputs per unit length based on the characteristic diagram of Fig. 2. This result is shown in a column E of table.

Table

A	B	C	D	E
Axial distance from position of exothermic center (mm)	Design output (W/cm)	Surface temperature corresponding to design output (°C)	Measurement temperature (°C)	Output (W/cm)
390	0.67	188	182	0.63
310	0.81	212	216	0.82
230	0.91	231	234	0.92
155	0.99	246	246	0.99
78	1.04	255	255	1.04
0	1.05	258	257	1.05
78	1.04	255	253	1.03
155	0.99	246	244	0.98
230	0.91	231	233	0.92
310	0.81	212	212	0.81
390	0.67	188	180	0.62

Then, in the characteristic diagram expressing a relationship among the axial distance, output and surface temperature of measurement spots of the sheath heater as shown in Fig. 3, the design output of sheath heater was formed /4 as line B, its surface temperature distribution as line C, its measured surface temperature distribution as line D and its

output distribution as line E. If the design output and surface temperature distribu-tion and the measured design output and surface temperature distribution are contrasted based on this characteristic diagram, the followings are introduced. Namely, the actual values have a dispersion of within nearly ±5% to the design values (specification values), thus it is a good product. (Nearly ±7% is generally taken as specification tolerance).

Moreover, if the measuring method of present invention is carried out in the output distribution measurement of a sheath heater used in a pseudo exothermic body of nuclear fuel of nuclear reactor, this method is very effective because it is required that this sheath heater accurately have a predetermined output distribution, but the method is also applicable to other sheath heaters.

As described above, when the output distribution measuring method of present invention measures the output distribution in a heater with a non-uniform output distribution, the method can accurately measure the output distribution actually needed in a heater product by the method of measuring surface temperatures and converting them to outputs.

IV. Brief Description of the Drawings

Fig. 1 is an illustrative diagram showing one actual example for measuring the surface temperature of a sheath heater in the

invented method, Fig. 2 is a characteristic diagram showing a relationship between the output and the surface temperature in a reference sheath heater, and Fig. 3 is a characteristic diagram showing the design and measurement output distribution and surface temperature distribution in a measurement objective heater.

1 J sheath heater

2 J · outer pipe

4 J thermometer

Fig. 1

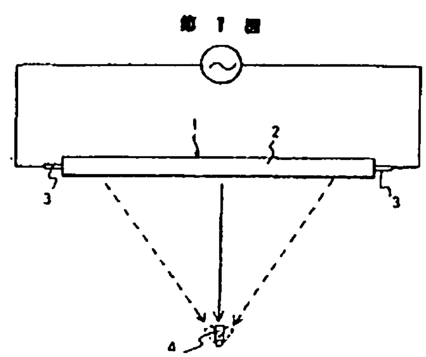
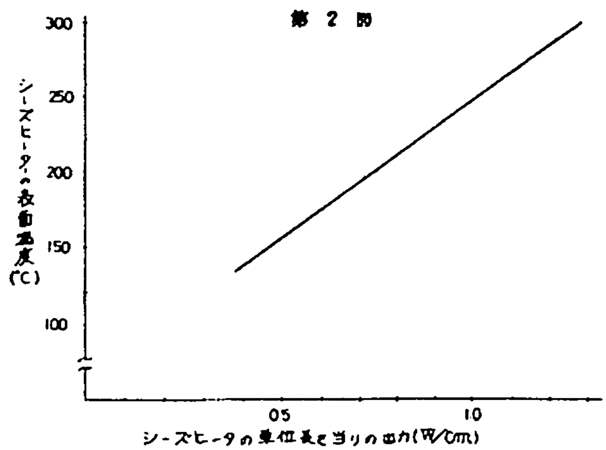


Fig. 2



Surface temperature of sheath heater (°C)

Output of sheath heater per unit length (W/cm)

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Fig. 3

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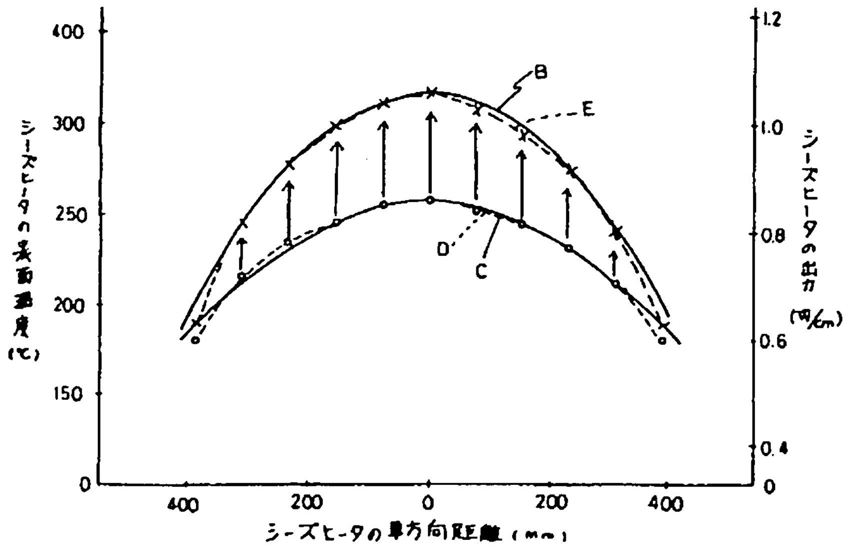

Surface temperature of sheath heater (°C)

Output of sheath heater (W/cm)

Axial distance of sheath heater (mm)